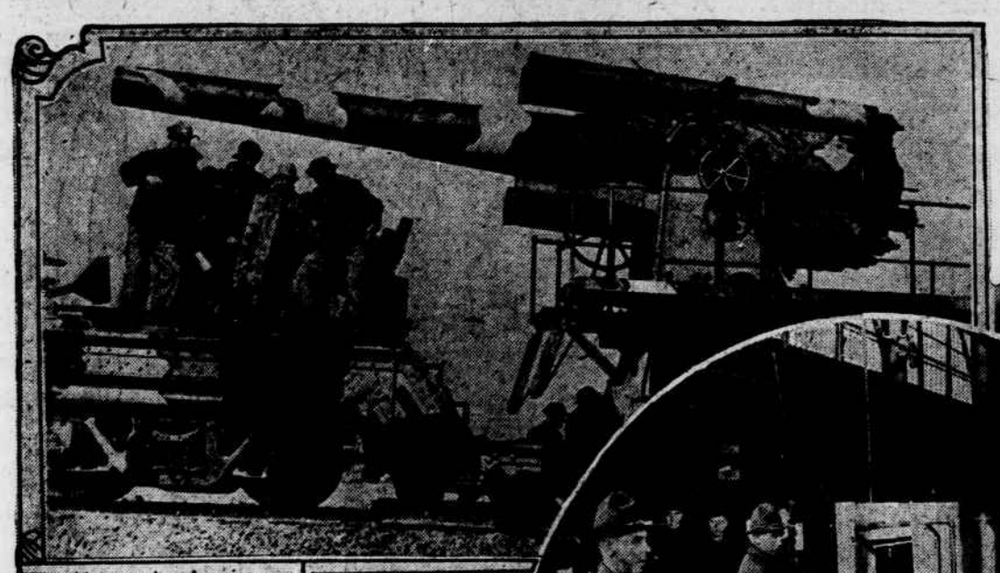
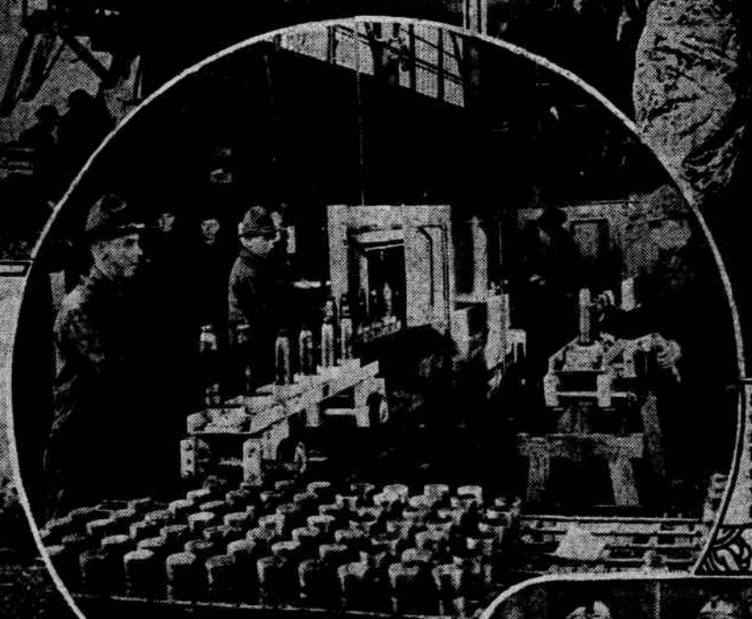
# SCIENTIFIC MARVELS DEVELOPED BY THE WAR

**The Superiority of American and Allied Chemists Overwhelmed Germany—Defeat Complete and Permanent.**



The big surprise America had in store for Germany was the eight inch seacoast long range gun mounted on railway trucks, for throwing huge gas shells twelve to fifteen miles; we had nearly 50,000 shells ready for these guns when the war ended.



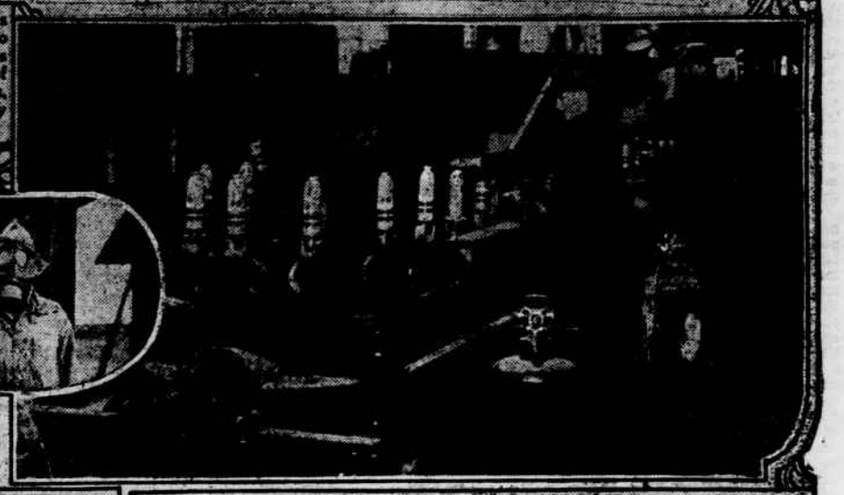
Loading 75-millimeter shells with mustard gas at Edgewood Arsenal. The soldier on the right is sending empty shells into the automatic loading chamber, the ones on the left removing the loaded shells as they come out. Note the military police ready to sound the gas alarm.

From left to right, the American, British, French and German gas masks; the American was the only one that would withstand the American mustard gas.

Since a horse never breathes through its mouth it is easy to fit it with a gas mask; horses have survived gas attacks of several hours without masks, when men have been fatally gassed.

Each of these cylinders contains enough poison gas to kill a regiment of soldiers.

American gas projector, ready to be fired electrically by an operator who may be a mile or more to the rear.



Painting 75-millimeter gas shells with the stripes and marks that indicate the character of their contents to the artillerymen. Each kind of gas is indicated by different color and striping.

The Edgewood Arsenal, where poison gas for chemical warfare is made and loaded into shells and bombs. More deadly chemicals than have ever before been gathered in one place are stored here



By FRANK P. STOCKBRIDGE.

There is no phase of applied science in which German supremacy at the beginning of the war was so definite as in the field of chemistry; there is no field in which Germany's defeat has been so complete and so permanent. Prior to 1914 Germany had for nearly forty years been the world centre of chemical industry.

Few important chemical discoveries were ever made by German scientists, but with the aid of government subsidies huge industrial enterprises based upon the researches of scientists of other nations were developed, competition by other nations crushed by means of underselling and sharp trade practices and an absolute monopoly established in scores of chemical products which modern civilization had accustomed the whole world to regard as necessaries of life.

All the huge industrial machinery devoted to chemical manufactures in Germany was at the disposal of the German government. When the war began not only the physical plants but the skill and resourcefulness of tens of thousands of chemists, trained for just this emergency in the German technical schools and universities were thrown into the scales against the Allies. In a sense, the greatest victory of the war was won when American and Allied chemists matched science against science, not only in the game of war, but in the intensive application to the arts of peace of the knowledge which Germany fatuously believed she alone possessed.

German chemical science went down to defeat all along the line. In the direct shock of battle Allied chemistry met German chemistry and overwhelmed it; behind the lines America and Great Britain built up their defenses against the "war after the war" and established once for all the independence of the rest of the world in chemical industry. There is no other industrial development due to war pressure that is fraught with such lasting importance as the development of new chemical industries in America, and none that so immediately and directly touches the lives of everybody.

### Accepted German Challenge.

The most spectacular and dramatic challenge by German chemistry was the use of poison gas as a weapon of war. The wave of indignation that swept over the civilized world at the news that came from the battlefield of Ypres, when 5,000 Canadian soldiers were suffocated by gas in the spring of 1915, was hardly exceeded by such atrocities as the sinking of the Lusitania or the murder of Edith Cavell. The Allies were slow to retaliate in kind; respect for the rules of civilized warfare, of which gas was in direct contravention, restrained them for more than a year. But when the basic law of self preservation at last compelled them to meet the enlarged volume and increasing deadliness of German gas by the use of the same weapon, there were no halfway measures taken.

By the summer of 1918 the Allied and American forces were delivering against the Germans daily five times as great a volume of poison gas as the Germans were using.

The "stoping power" and deadliness of the gases used on the Allied side was definitely greater than the German gases possessed.

Not only did the Allies analyze, match and improve upon every form of poison gas the Germans used, but American chemists developed a poison gas having seventy-two times the killing power of the deadliest German gas!

It is literally true that had the war gone on to the spring campaign, for which America's preparations were being focussed, we would have been able, by the use of this new gas, actualy to smother the German army by divisions at a time. Newly designed gas bombs of greater capacity than anything that had previously been attempted, with special mortars for hurling them into the enemy's lines at long range, had been perfected and were in process of manufacture when the armistice was signed. When one of these bombs burst there would have remained no living thing within a radius of hundreds of yards a few moments later!

### Gas Secret Not Disclosed.

This new and nameless gas, the chemical secret of which has not yet been disclosed, but whose deadliness is vouched for by army officers of the Chemical Warfare Service, was made in Cleveland in a plant known to the men who worked in it and initiated outsiders as "the rat trap." Surrounded by a high, close meshed barbed wire fence, guarded at all times by sentries with loaded rifles and brightly illuminated at night, "the rat trap" is as sinister in appearance as its name indicates.

Men who went into the "rat trap" to work did not come out; no chance could be taken on the leakage of secrets. When the war ended there were men in the plant who had not been beyond the wire fence for almost a year; most of the workers had been inside for months. None but men whose whole careers bore the most rigid scrutiny by the investigators of the Army Intelligence Service were employed, even though they had taken the oath of allegiance as soldiers, so fearful were the authorities that some inkling of what was in store for the Huns would leak out prematurely, although chemists familiar with the new gas are a unit in declaring that by no possible means could the Germans have defended themselves against it. The best gas mask known would be as useless as mosquito netting.

### Mustard Gas Extremely Fatal.

I have said that this new gas is estimated to be seventy-two times as deadly as "mustard" gas; let me try to convey an impression of just how deadly that is.

Mustard gas, as made in the Edgewood Arsenal, near Baltimore, where our war gas production is centred, penetrates the clothing and shoes of men exposed to it, causing frightful burns. A single drop has been known to cause a fatal burn. Only the most perfect ventilating system and the wearing of masks, rubber gloves and rubberized protective clothing by those engaged in the dangerous processes of its manufacture made it possible to make it at all. Even with these precautions the casualties at the Edgewod Arsenal ran an average of three per cent. a day, and when the armistice was signed there were 300 men in the camp hospital suffering from mustard gas burns, and many others had been invalided to reconstruction hospitals.

A soldier who had been handling some of the ingredients of mustard gas brushed a mosquito from his ear without first removing his glove; two days later his ear had literally been burned off.

An officer came out of the laboratory into one of the offices. Carelessly he rested his glove encased hand on the back of a swivel chair while he chatted for a few minutes. The next day the officer who sat in the chair felt a burning pain in the upper part of his back; two days later he was dead. The mustard gas had burned into his spinal cord. It takes two pounds of mustard gas to load a seventy-five millimeter shell; at the signing of the armistice we had on hand 419 tons of this stuff—enough to load 419,000 shells. The charge of one shell is calculated to put out of action every one within fifty yards when it explodes.

### Want to Sink Gas at Sea.

Mustard gas is one of the finished products of our war preparations for which there is no peace time use. The great plants built to produce the chemicals that enter into its composition, however, and the huge supply of those chemicals, are a distinct addition to the nation's industrial assets. The army chemists want to take the stock of mustard gas out to sea and sink it, containers and all. The action of the sea water will neutralize the gas, they say. Fort authorities at New York have protested, fearing the gas may rise to the surface and asphyxiate the metropolis. More than once while hostilities were under way there were many tons of mustard gas in New York harbor, enough to kill every person in Manhattan if it were let loose with the wind blowing in the right direction.

The basis of mustard gas, as of the other war gases, is chlorine. The gas first used by the Germans at Ypres, in fact, was simply chlorine, and nothing else. It has a commercial use as a bleaching agent and electrolytic processes for its production from sodium chloride—common salt—were well known, but there was not enough being produced annually in the whole United States when this country entered the war to supply the army's needs for a week. So at the Edgewood Arsenal there was built a huge plant for the decomposition of brine by electricity, and the collection of the products of decomposition—chlorine, caustic soda and hydrogen. This plant, the largest in the world, is said by American and foreign chemists who have inspected it to be also the most efficient and economical in operation. Its capacity of 100 tons a day of chlorine will be, it is expected, available for commercial purposes under conditions yet to be determined.

The process of making mustard gas had to be worked out by scientists after unexploded German gas shells containing this new poison had been analyzed by other chemists, and the exact nature of the gas ascertained. Whether by reason of a better process or purer raw materials, American mustard gas is more powerful than the German. Gas masks that provided perfect protection for our troops against the most powerful German gas were not enough protection against our own, for the workers in the Edgewood Arsenal, who had always to be prepared to respond to a gas alarm. So a new gas mask was invented and issued to our troops, as well as to the gas workers.

### Trace Gas Constituents.

To trace back the constituents of mustard gas and the other poison gases to their sources and describe the new methods and processes that had to be developed before we could make a ton of "dichlordiethlysulphide," which is the technical name for mustard gas, would make an interesting book in itself. First there had to be insured an ample supply of pure sulphur, through which the chloride could be passed to make chloride of sulphur; then processes devised of producing ethylene, a constituent of coal gas, but which may also be made by treating sulphuric acid with pure alcohol. For these and other war purposes there have been wonderful developments in the production of sulphur and of alcohol, concerning which I shall tell some of the interesting phases in later articles.

Picric acid, the high explosive that forms the basis of the British lyddite, the French melinite and the Japanese shimose, was being manufactured in large quantities in this country for the British before the United States entered the war. It was made by treating carbolic acid with a mixture of sulphuric and nitric acids; we had to develop a carbolic acid industry to supply the demand from this and other sources that had formerly been filled from Germany. Then the Division of Chemical Warfare devised a combination of chlorine and picric acid, known as chlor-picrin, which answered the same purpose in warfare as the early German gases, in that it put men out of action without necessarily killing them unless they were exposed to it for a long time.

There is no particular use in industry for the 511 tons of chlor-picrine we had left on hand when the war ended, but the picric acid industry, now firmly established in America, is of great value. Picric acid was not used as an explosive until very recently; as a dyestuff it has been known for 150 years. It is, in fact, the very first of the synthetic chemical dyes to have become commercially successful. With an ample supply of picric acid available, the yellow dyes for which the world was formerly dependent upon Germany can now be made in America; with the utilization of other products which the war compelled us to learn to make, it may fairly be said that we are already independent of Germany in the matter of dyestuffs; how far and in what directions we have gone in the dye industry I shall tell you in a later article.

Most valuable of all the by-products of the Edgewood Arsenal [illegible] its production a distinct commercial triumph, is phosgene. In point of military effectiveness phosgene ranks [illegible] chlor-picrine and mustard gas: it is the [illegible] the largest quantity was used by the Germans, and when the armistice was signed the United States had the largest [illegible] in the world for its manufacture, [illegible] 1,308,000 pounds of this gas on hand. It is made from common salt. White phosgene is made from bones after they have been boiled to extract all the gelatinous matter for glue. We had 1,220,000 pounds of this material on hand when the war ended, 606,000 pounds of stannic chloride and 896,000 pounds of titanium tetrachloride.

The three last named chemicals were made in outside laboratories and shipped to the Edgewood Arsenal to be placed in shells and bombs for shipment overseas. Nothing could be more ingenious or effective than the immense, almost completely automatic plants for filling shells with these deadly chemicals. There were no precedents to go by. Everything had to be designed from the blank paper before construction could be even begun, but so effective was the machinery when once installed that nearly 200,00 shells, bombs and grenades were being filled every week when the war ended. Every precaution that human ingenuity could devise was installed to make it possible to do this work with the least possible risk to the men engaged; nevertheless it was so difficult to obtain civilian help that finaly it was all, or practically all, done by soldiers detailed for the purpose.

### Figures in Production.

Here are some figures from the confidential records of the War Department that give perhaps as impressive an idea as can be obtained of the full scope and extent of our gas warfare preparations. When the armistice was signed we had on hand, finished and loaded, or ready for loading, 1,556,886 seventy-five millimeter gas shells; 92,496 gas shells for 4.7 inch guns; 629,910 gas shells for 155 millimeter guns and howitzers; 739,854 hand grenades filled with stannic tetrachloride, and besides a miscellaneous supply of other kinds of gas shells and bombs and gas projectors there were ready for use 48,349 gas shells for eight inch seacoast guns. And on this later item hangs one of the war secrets that has not been so far disclosed.

It was not until the very end of hostilities that it was learned that a couple of fourteen-inch navy guns on railroad mounts had been used by the American forces on the western front. Then it was announced that the navy's experiment with these guns had been so successful that the army had in readiness or preparation a considerable number of large caliber guns mounted on railroad trucks for use in the spring campaign. But not until now has it been published that these eight-inch seacoast guns were to be used to hurl the largest gas shells ever made twelve of fifteen miles, if need be, and the charge of the new "mystery gas" each shell would carry would literally wipe out an entire regiment of Germans.

### Effects Enormous Saving.

"A value to the United States equal at least to the whole cost of the Chemical Warfare Division for the period of the war can be credited to the cheap and simple method of producing phosgene developed at Edgewood Arsenal," said an officer who is a chemical engineer when not in uniform. "The government has distributed samples of phosgene large enough to be used commercially to a large number of industrial concerns, together with complete detailed formulas. Nothing could be more helpful in the establishment on a permanent basis of the dye industry than to have this knowledge available."

Phosgene is the basis of a wide variety of colors. Numberless greens, brilliant scarlet, yellows, violets and blues are all made by means of aniiin combinations with phosgene in different proportions and ways. It also has the property of attacking iron oxide and utterly absorbing it. Brickwork at the Edgewood Arsenal has been bleached almost white where phosgene has come in contact with the iron oxide which gives ordinary bricks their red color. Another extremely important use of this gas is in destroying the brownish tones of glass, due to the presence of minute quantities of iron oxide in the sand from which the glass was made. Part of the sucess of American glassmakers in producing a clear optical glas for photographic and other lenses, which I described in last week's article, was due to the use of phosgene for this purpose.

### Invented Phosphorous Bombs.

Besides the gases already referred to the 2,000 expert chemists and 10,000 and more soldiers and special employees who took part in the work of the "offensive" section of the Chemical Warfare Division devised ways for producing on an unprecedented scale such interesting commodities as white phosphorus, which burst into flame on the last contact with dampness—even ordinary damp air—and gives off an intense white smoke, used for filling incendiary and smoke bombs; stannic tetrachloride, the product for which we were all urged to save tin, a gas that was found most effective for driving boches out of their dugouts, and titanium tetrachloride, equally lethal. Note the "chlor" syllable in all of these gases, indicating chlorine as one of their composition and their derivation from common salt. White phosporus

### Sees Huge Gun in Action.

I saw one of these guns at the Aberdeen proving grounds, adjoining the Edgewood Arsenal, recently. Originally designed for coast defence, they are of high power and long range. Mounted on railway trucks they can be moved quickly from point to point behind the lines, and the mounting is so designed that the gun is ready to fire within five minutes after arriving at the designated spot. It does not take a very vivid imagination to picture the havoc that half a dozen well placed shots from one of these weapons, charged with the most deadly gas yet devised, would have worked on the German morale.

General Gouraud, the famous one armed French commander, said to the American newspaper correspondents the other day that brutal and savage as this war has been the next war would be even more brutal and savage. It will begin where this one left off—but it would be difficult to imagine a more potent discourager of war than the knowledge that the enemy possesses such weapons as gas resources which the United States now has. If in addition to the enormously valuable contributions to peaceful industry which I have indicated, America's preparations for chemical warfare prove a deterrent of future wars they will have easily been worth all they have cost us.

"The most spectacular and dramatic challenge by German chemistry was the use of poison gas as a weapon of war. The wave of indignation that swept over the civilized world at the news that came from the battle field of Ypres, when 5,000 Canadian soldiers were suffocated by gas in the spring of 1915, was hardly exceeded by such atrocities as the sinking of the Lusitania or the murder of Edith Cavell. The Allies were slow to retaliate in kind; respect for the rules of civilized warfare, of which gas was in direct contravention, restrained them for more than a year. But when the basic law of self-preservation at last compelled them to meet the enlarged volume and increasing deadliness of German gas by the use of the same weapon, there were no half-way measures taken. By the summer of 1918 the Allied and American forces were delivering against the Germans daily five times as much poison gas as the Germans were using."